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Fine Structure of Lymphatics in the Myocardium

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Summary

Myocardium contains a loose network of lymphatics. The wall of cardiac lymphatics consists of a flat endothelium without a continuous basal membrane. In the normal heart, lymphatic endothelium shows an extensive folding. In inflammatory edema of the interstitium, lymphatic lumina become unfolded, intercellular junctions of endothelial cells open, and many lipoproteid complexes occur in endothelial cytoplasm. The cardiac lymphatic system is regarded as a vascular drainage system which increases in importance under pathologic conditions.

Introduction

The lymphatic system of the heart muscle was discovered by *Rudbeck* (1653). *Eberth* and *Belajeff* (1866) described the course of lymph vessels not only in myocardium but also in the heart valves and accompanying the conduction system. Since these first descriptions, the existence and the course of myocardial lymphatics from endocardium via transverse branches to the epicardial lymph collecting vessels has been proven (1, 26). *Johnson* and *Blake* demonstrated communicating subendocardial and subepicardial lymphatics by injection of H_2O_2 and India ink. Experimental pathological and pathophysiological investigations in function of cardial lymphatic system have been reported (9, 17, 18, 19). In agreement with the results of *Földi, Miller* and *Kline, Solti* and coworkers showed that ligature of cardiac lymph vessels intensified the consequences of coronary occlusion. *Celis* and coworkers supposed that the healing of infarcts depended on an intact lymph vessel system and sufficient lymph stream.

In human medicine, an important pathogenetic influence of the lymph vessel system is assumed in lesions of the lymphocytic system, in fibroelastosis of the endocardium, in rheumatic pancarditis and in isolated myocarditis (11, 24). *Verèss* and coworkers observed imbibition by plasma of smaller coronary artery branches after cardiac lymphostasis in dogs. When lymphostatic edema subsided, a fibrosis of the arterial media persisted. In heart transplantation, the cardiac lymph vessel system should be carefully examined (22, 21).

This study is concerned with the electron microscopic structure of the smaller cardiac lymph vessel branches, and their relation to the surrounding interstitial tissue.

Material and Methods

Three or 4 different pieces oft left ventricular wall were obtained from 5 normal rats, 3 normal mice and 5 mice with beginning viral myocarditis. For electron microscopic investigations, the tissue was fixed in buffered glutaraldehyde (105 min). After washing

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in buffered glucose solution, a second fixation was made with osmium tetroxide. Following dehydration by acetone, the muscle pieces were embedded in Durcupan (Fluka). Thin sections were obtained from a Porter-Blum microtome. Contrast was intensified by treatment with uranyl acetate and lead citrate according to *Reynolds*. Electron micrographs were done with a RCA-EMU-E-microscope.

Results

In the myocardium lymph capillaries are rarer than blood capillaries. Interstitial lymphatics are in tight contact with the basal membranes of surrounding blood capillaries, nerves, fibrocytes and muscle fibers (Fig. 2, 3, 4). The lymphatic wall consists of a flat endothelium which in normal stage is extensively folded (Fig. 1). Because of folding of endothelium the capillary lumen sometimes is difficult to identify. Nuclei of endothelial cells are coarse and hyperchromatic. The pale osmiophobic cytoplasm contains only a few small organelles. Ribosomes can be found diffused and arranged in polyribosomes. Membrane vesiculation is marked. Endothelial junctions differ from extensive interdigitation to close connections and open junctions between capillary lumen and interstitium (Fig. 6). Specific junctions or desmosomes cannot be found.

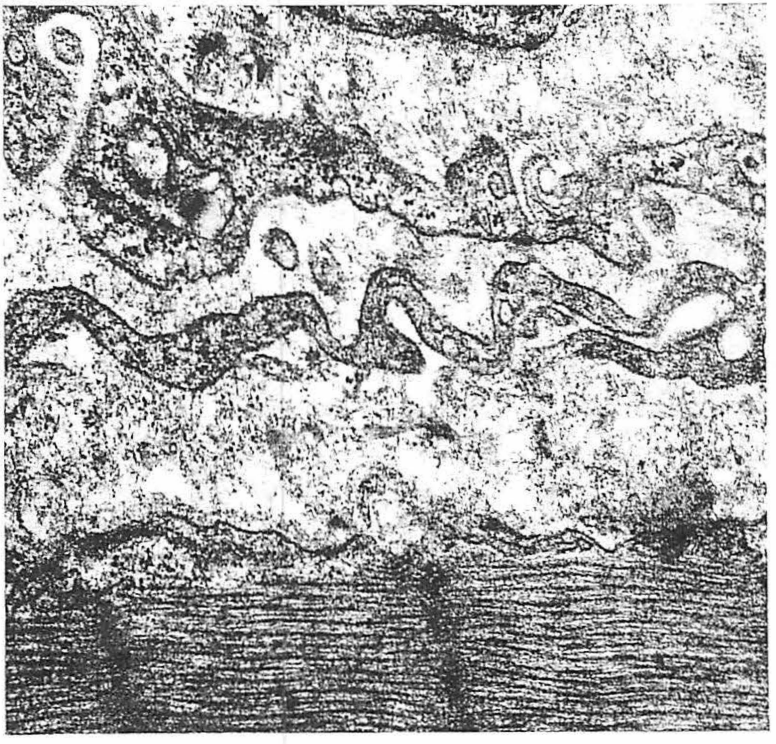

Fig. 1 Longitudinal section of a collapsed lymph capillary with folded endothelium beside a heart muscle cell. – Electr.-micr.: 15,000; total magnif.: 40,000.

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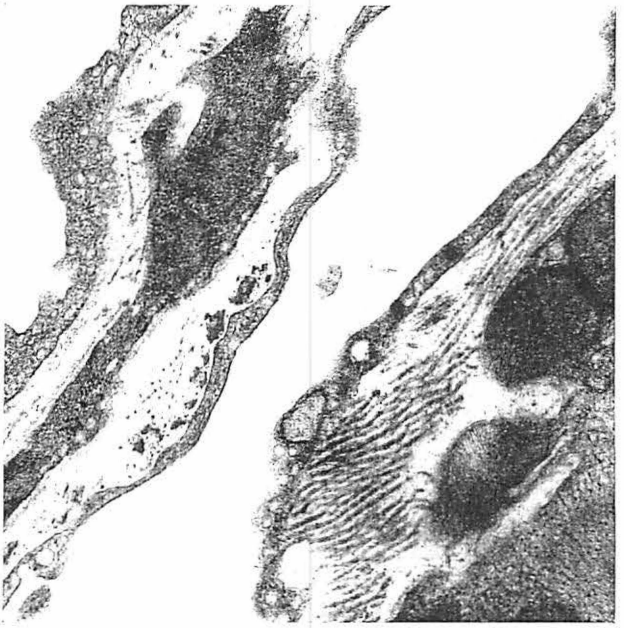

Fig. 2 Unfolded lymph capillary surrounded by collagen fibrils and finer filaments. In the top (left) a blood capillary. Electr.-micr.: 2100; total magnific.: 4000.

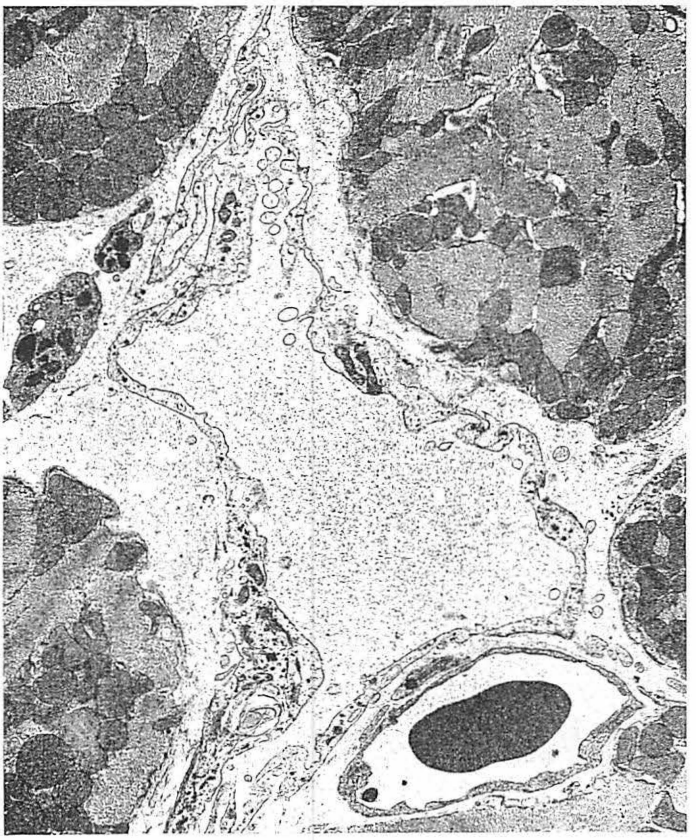

Fig. 3 Strongly unfolded lymph capillary above a blood capillary in interstitium of heart muscle 2 days after injection of EMC-virus. Electr.-micr.: 2500; total magnific: 8000.

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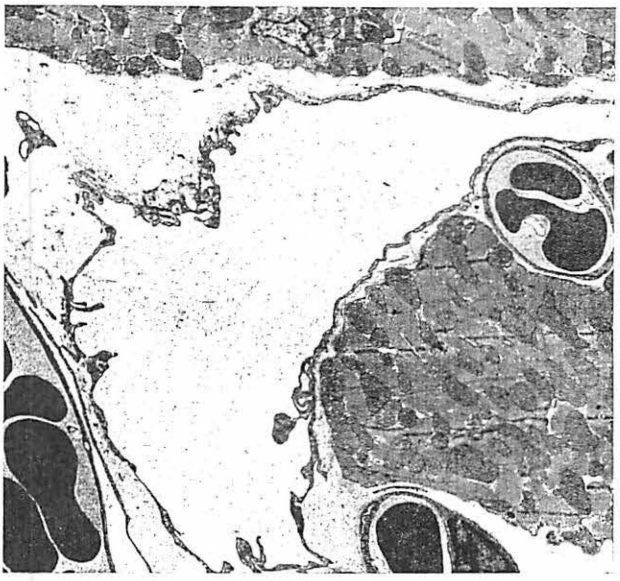

Fig. 4 Marked degree of lymph capillary ectasia with surrounding congested blood capillaries 3 days after virus injection.

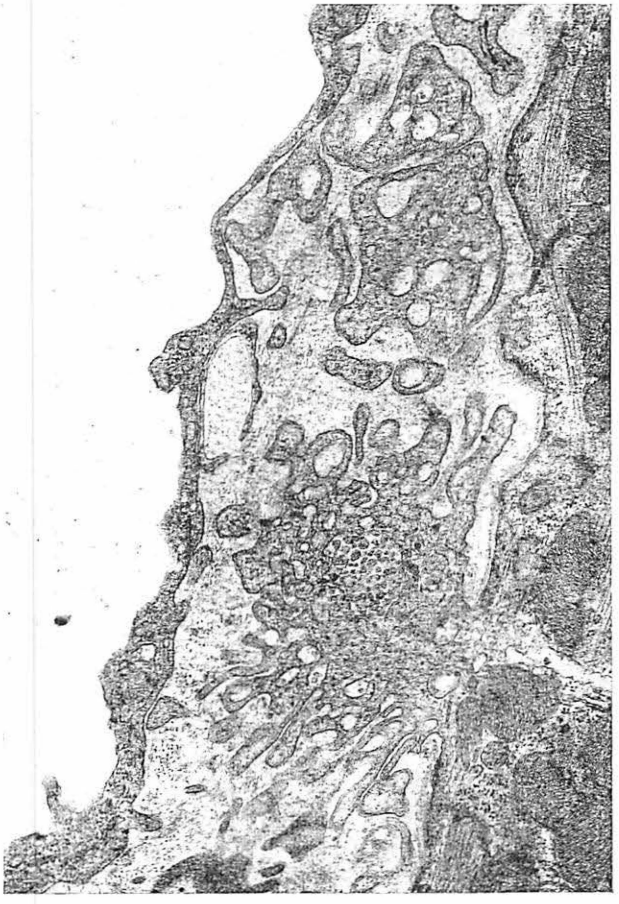

Fig. 5 Distended lymph capillary wall beside myocardial interstitium with folded protrusions of sarcoplasm. Electr.-micr.: 6200; total magnific.: 20 000.

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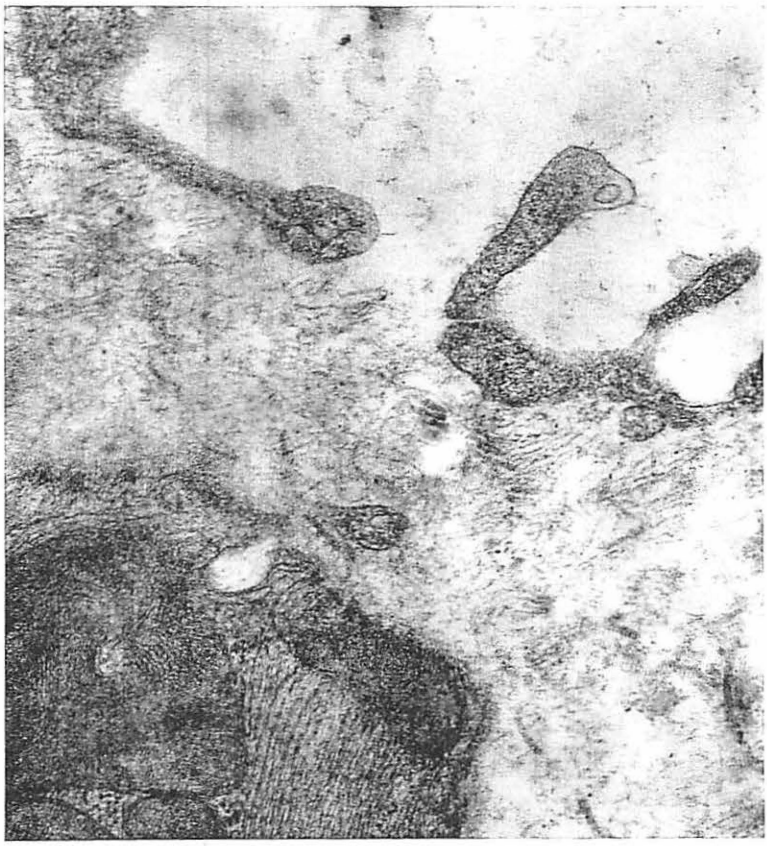

Fig. 6 Open endothelial junction of a lymph capillary. The endothelium is surrounded by a dense network of fine filaments. – Electr.-micr.: 15,000; total magnific.: 45,000.

Rarely, the outer endothelial cell membrane is based upon discontinuous dense stripes, which resemble basal membranes but are not as broad as those of blood capillaries. Lymphatic endothelium is surrounded by collagenic fibrils, often at an acute angle to the endothelial cell border. In addition, the endothelial cells are fixed in a net of fine filaments, which are much thinner than collagen fibrils (Fig. 2, 6). Differences of lymphatic arrangement and wall structure do not exist in the investigated animals.

Viral myocarditis is accompanied by interstitial edema in the first phase, when cellular exsudation has not yet taken place and blood capillaries are not yet altered (Fig. 3, 4). During development of interstitial edema, a progressive stretching of lymph capillary endothelium arises (Fig. 2, 5). The endothelial stretching is in accordance with an unfolding of the capillary lumen (Fig. 2, 3, 4). The lymphatic lumen is larger than that of blood capillaries. The number of open endothelial junctions increases with the severity of edema. In the cytoplasm of lymphatic endothelium, there occurs an

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increasing number of cytosomes with a matrix of different density. Some of the endothelium remains thin, but some endothelial cells become broadened by phagocytised lipoproteid complexes.

Discussion

The structures of lymph capillary wall in the myocardium do not differ from those in parenchymatous organs. Corresponding to findings in liver or kidney a continuous basal membrane is lacking in the lymph capillary wall of myocardium (27, 12, 13, 10, 29). Numerous open cell junctions of cardiac lymphatics support the idea that this capillary system can be adapted very quickly to functional load. Intensive overlapping of endothelial cells as described by *Ottaviani* and *Azzali* (1966) in chyliferous vessels of intestinal villus does not occur in myocardium. In agreement with the low cardiac lymph flow under normal conditions, the lymphatics of normal heart are collapsed with much folding of their endothelium. Interstitial edema, such as that in viral myocarditis, induces an extended unfolding of lymph capillaries. *Kline* (1969) already stated that unfolding of cardiac lymph vessels should draw attention to such severe pathologic processes as infarction, myocarditis or obturation of lymph collecting vessels, for example in the mediastinum. Drainage of cellular and metabolic products, corpuscular substances and edema rich in protein is regarded as essential function of lymphatics in every organ. An unfolding of cardial lymphatics therefore can be induced, if the mentioned conditions take place (9, 17, 18, 19, 23, 24, 30, 6, 31). *Goldberg* observed unfolding of lymphatics by their cell content in myelosis and lymphomas. The observed stretching of endothelial cells in myocarditis is simulated under other conditions in other organs (3, 4, 5, 20). The increase in open cell junctions as well as the increase in lipoproteid complexes within endothelia should be regarded as signs of an intensified resorptive activity in an edematous interstitium. Opening of lymphatic walls in the edematous interstitium also makes it obvious that cardiac lymph vessels have a function, which becomes efficient in acute loads of edema rich in protein. Further investigations in cardiac lymph vessel system should promise to be interesting.

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